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EXTERIOR WEATHERING DURABILITY OF SOME LEACH-RESISTANT FIRE-RET--ETC(U)

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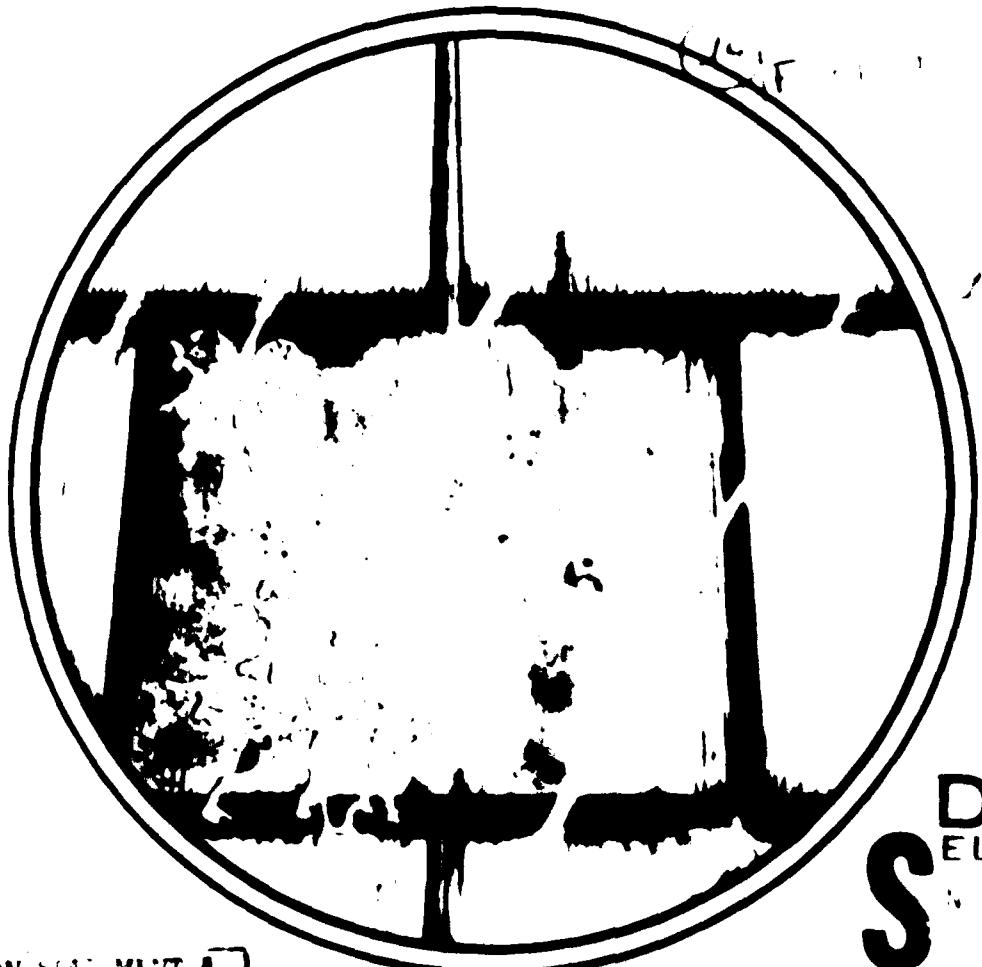


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# Exterior Weathering Durability of Some Leach-Resistant Fire-Retardant Treatments for Wood Shingles: A Five-Year Report.

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## Abstract

As a part of a continuation study on fire-retardant treatments for wood shingles and shakes, shingles were treated by systems selected from previous research, including commercially treated class C shingles, and exposed outdoors for 2, 5, and 10 years. This is a progress report after 5 years' exposure and fire testing by burning brand and modified Schiwyer tests.

Generally acceptable results were obtained after 2 years' exposure, except for a reference pyreosote treatment. After 5 years' exposure, all systems passed 80 percent or more of the burning brand tests except for the pyreosote and the pyreosote with light sealer coating. All systems showed weakness in the Schlyter, but in four of the eight systems flames on shingles were self-extinguishing.

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### Conversion of Units

1 Btu/h	=	0.2931 W
1 ft	=	0.305 m
1 in.	=	25.4 mm
1 lb/ft <sup>3</sup>	=	16.02 kg/m <sup>3</sup>
1 mil/in	=	0.447 mm
T (°F)	=	1.8 T (°C) + 32

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# Exterior Weathering Durability of Some Leach-Resistant Fire-Retardant Treatments for Wood Shingles: A Five-Year Report

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## Introduction

One of the distinct advantages of using wood for a roof covering is its remarkable resistance to weathering. Some of the wood shingles on the roofs of seventeenth-century houses in Massachusetts Bay, Mass., are about 300 years old (8). This high natural durability to the effects of water, wind, sunlight, and temperature change, together with good insulation effect and desirable appearance, have continued to keep wood shingles and shakes in demand for residential roofing.

Unfortunately, some large fires involving untreated wood roofs have occurred and been widely publicized. The result is that some jurisdictions are limiting the use of untreated wood roof coverings on certain occupancies by requiring class C, or better, shingles. Untreated wood cannot meet the required conditions for class C as set forth in ASTM E 108 (3). The editor of a National Fire Protection Association publication is encouraging a total ban on the use of untreated wood shingles and shakes (11).

<sup>1</sup> Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

<sup>2</sup> Reference numbers in parentheses refer to Literature Cited at the end of report.

Fire-retardant-treated wood shingles and shakes are available that meet class C roofing requirements (5, 9). The initial acceptance of the treatment system is based on fire performance after an accelerated leaching exposure (2, 3, 12). Follow-up testing is carried out after periods of outdoor exposure by an independent testing laboratory (13).

This publication is a progress report on a continuation study at the Forest Products Laboratory of the exterior or outdoor durability of fire-retardant treatments for wood shingles.

## Previous Research at FPL

In prior research at FPL various fire-retardant-treatment systems for wood shingles and shakes were evaluated by laboratory methods (7) for their fire performance and durability. Shingles and shakes of western redcedar (*Thuja plicata* Donn) were used in the initial phases of the study.

The selected fire-retardant treatments were first evaluated for method of application and general fire performance under three fire test methods: the 8-foot tunnel furnace (ASTM E 288-69) (1); the modified Schiwyer test (14); and a modified class C burning-brand test (ASTM E 108-58) (3).

The treatment systems that showed promise were then evaluated for durability under two exposure conditions. The first was a 28-day outdoor leaching exposure with a daily water spray plus natural rainfall totaling 30 inches, the approximate average annual precipitation in the United States. After being conditioned to constant weight at 80° F and 30 percent relative humidity, the specimens were fire tested to eliminate the less durable treatments and provide information for adjustment in levels of chemical retention. In the second exposure, the remaining treatment systems were given a 1,000-hour exposure in a weathering apparatus developed for the purpose (2, 8). This subjected the specimen panels of treated shingles to cyclic exposure of water spray and sunlamp radiation at 150° F. After conditioning, the specimens were fire tested by the modified Schlyter and burning-brand methods.

Treatment systems that showed promising fire-retardant effectiveness in the prior research were vacuum-pressure impregnations of: Tris (1-aziridinyl) phosphine oxide (APO) (codes 25 and 26 in (7);<sup>1</sup> tetrakis (hydroxymethyl) phosphonium chloride (THPC) with urea and melamine (code 29); dicyandiamide and phosphoric acid (DP) (codes 33 and 34); dicyandiamide and phosphoric acid and formaldehyde (DPF) (code 32); and pyresote (formerly AWPA type D), with five spray applications of a sealer solution consisting of 20 percent, by weight, tricresyl phosphate, and 80 percent water-repellent-preserved (meeting Federal Specification TT-W-572 Type II) containing mineral spirits, a water repellent, pentachlorophenol, and other chlorophenols (code 24). A sixth treatment system indicating some promise was an epoxy type fire-retardant paint (code 13). The results on these systems were evaluated using the performance of the commercial class C-labeled shingles (code 36) as reference.

The logical followup was the actual outdoor exposure over time of the shingles treated with variations of the most promising systems. This paper reports results of modified Schlyter and burning-brand tests after 2 and 5 years of exposure. Labeled shingles with the commercial treatment, NCX, are also included in this study for comparison.

#### Procedure

The specimen panel construction, moisture-content conditioning, and conduct of the modified Schlyter and class C burning-brand tests used in this study are the same as described in the report on the prior initial research (7). A description of each treatment system used in this study is given in table 1 and correlated by code number to the treatment systems used in the first phase. The promising treatment system APO, evaluated in the earlier research, was not included in this study because of the toxicity of the chemical. Shingles treated at FPL by the vacuum-pressure method were

kiln dried at temperatures not exceeding 130° F until they reached about 6 percent equilibrium moisture content (EMC). Shingles treated with DP or DPF were dried at 130° F until they reached 6 percent EMC; kiln temperature was then increased slowly to 180° to 185° F and held for 24 hours.

For each treatment system and level of retention, eight Schlyter specimen panels and eight burning-brand specimen panels were made up. All specimen panels were conditioned to constant weight in a room maintained at 80° F and 30 percent relative humidity (RH). Two Schlyter panels and two burning-brand panels of each treatment system were fire tested as controls without exposure. The other panels were placed outdoors in the Madison area on racks facing south at a slope of 37.5° from horizontal (fig. 1) for 2-, 5-, and 10-year exposure periods. Observations of the exposed panels were made periodically to assess any visual degradation of the shingles. At the end of the 2- and 5-year exposure periods, one set of panels (two Schlyter and two burning-brand) of each treatment system and chemical retention level were removed from the exposure racks, conditioned at 80° F and 30 percent RH, weighed, and fire tested.

#### Results and Discussion

##### Photodegradation and Leaching

Outdoor placement of the shingle panels near Madison, Wis., exposed them to the typical temperature climate of interior North America with large temperature fluctuation and average annual precipitation. It did not represent the extremely adverse weathering conditions of continuing high temperature and high annual rainfall found in some parts of the United States. During the 5 years of outdoor exposure of the shingle specimens in this study, the mean annual precipitation at Madison was 32.1 inches, temperature extremes were -22° F and +104° F, mean annual percent of possible sunshine was 55, and average minimum and maximum relative humidities were 61 and 84 percent.

Two mechanisms are apparently involved in the leaching loss of fire-retardant chemicals from exposed treated western redcedar shingles. The first involves photodegradation and delibration of the surface wood cells by ultraviolet light (10, 15, 16). The result is discoloration usually to a gray color and loss of wood substance from the surface. This degradation process is enhanced by presence of water. Minute checking due to photodegradation becomes more severe so that the deteriorating wood surface becomes visibly checked and cracked and water is more easily absorbed.

In the second mechanism, water absorbed during rainfall penetrates into the wood and slow diffusion of the fire-retardant chemicals toward the surface occurs with resultant loss of the chemicals. High temperatures followed by rain promote water pickup by the wood due to the hot-cold bath effect. Air and water in the wood expand under heat and, when cooled by rain, contract

<sup>1</sup> Descriptions by code number are given in the appendix taken from previous FPL research report (7).

Table 1.—Description of fire-retardant treatments for western redcedar shingles used in outdoor exposure tests

Treatment	Method	Treatment formulation	System reference <sup>1</sup>
Untreated	None	—	
Fire-retardant epoxy paint	Brush coating	Manufactured commercially in accordance with Military Specification MIL-C-46081.	Code 13
THPC-1	Pressure impregnation	Treating solution: Tetrakis (hydroxymethyl) phosphonium chloride (80% in water) 12.55%, sodium hydroxide (50% in water) 2.16%, urea 2.05%, a liquid melamine 4.35%, water 78.89%.	Code 29
THPC-2	Pressure impregnation	Treating solution: Tetrakis (hydroxymethyl) phosphonium chloride (80% in water) 18.86%, sodium hydroxide (50% in water) 3.24%, urea 2.88%, a liquid melamine 6.47%, water 68.65%.	Code 29
DPF-1	Pressure impregnation	Treating solution: Dicyandiamide 8.64%, phosphoric acid (85%) 11.83%, formaldehyde (37%) 0.83%, water 78.7%. Solution preacted.	Code 32
DPF-2	Pressure impregnation	Treating solution: Dicyandiamide 10.90%, phosphoric acid (85%) 14.86%, formaldehyde (37%) 1.05%, water 73.10%. Solution preacted.	Code 32
DP-1	Pressure impregnation	Treating solution: Dicyandiamide 6.98%, phosphoric acid (85%) 9.45%, water 83.57%.	Code 33
DP-2	Pressure impregnation	Treating solution: Dicyandiamide 9.3%, phosphoric acid (85%) 12.8%, water 78.1%.	Code 34
Pyresote-1	Pressure impregnation	Treating solution: Zinc chloride 7.92%, ammonium sulfate 7.92%, boric acid 5.86%, sodium dichromate 1.13%, water 77.38%.	Code 24
Pyresote-2	Pressure impregnation	Treating solution: Zinc chloride 5.95%, ammonium sulfate 5.95%, boric acid 4.25%, sodium dichromate 0.86%, water 83.0%.	Code 24
Pyresote-3	Pressure impregnation and brush coating	Treating solution: Same as pyresote-1. Brush coating: Two applications of a solution consisting of 80% sealer A and 20% tricresyl phosphate. Sealer A is a mineral spirits solution containing a water repellent, pentachlorophenol, and other chlorophenols; it meets Federal Specification TT-W-572 Type II.	Code 24
Pyresote-4	Pressure impregnation and brush coating	Treating solution: Same as pyresote-2. Brush coating: Two applications of a solution consisting of 80% sealer A and 20% tricresyl phosphate.	Code 24
Pyresote-5	Pressure impregnation and brush coating	Treating solution: Same as pyresote-2. Brush coating: Four applications of a solution consisting of 80% sealer A and 20% tricresyl phosphate.	Code 24
UDFP-1	Pressure impregnation	Treating solution: Urea 1.08%, dicyandiamide 4.54%, formaldehyde (37%) 4.32%, phosphoric acid 7.08%, water 83.0%.	(9)
UDFP-2	Pressure impregnation	Treating solution: Urea 1.44%, dicyandiamide 6.03%, formaldehyde (37%) 5.75%, phosphoric acid 9.38%, water 77.4%.	(9)
NCX <sup>2</sup>	Pressure impregnation	Commercial treatment, class C labeled by Underwriters' Laboratories, Inc.	(5), Code 36

<sup>1</sup> Code numbers are from table 1 in (7).

<sup>2</sup> NCX is a registered trademark of Koppers Company, Inc.

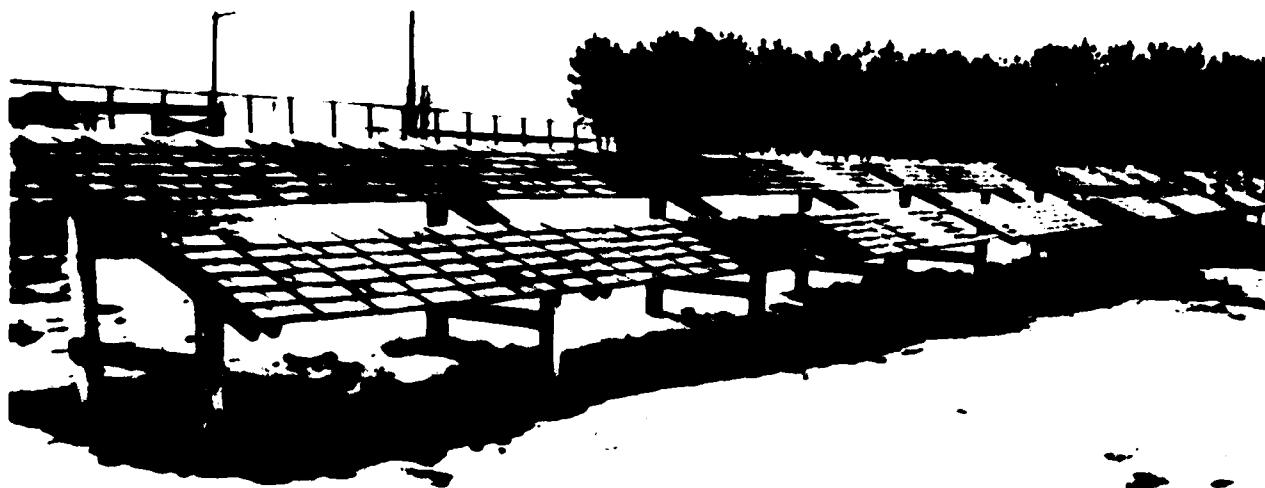


Figure 1.—Specimen panels of fire-retardant-treated shingles exposed outdoors near Madison, Wis.  
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and draw the rainwater deeper into the wood. During drying, the water and dissolved chemicals diffuse toward the surface.

These continuing processes eventually cause loss of fire-retardant chemicals and consequent reduction in fire performance effectiveness. The amount of chemical loss and its effect on performance will depend on the degree of leach-resistance or water solubility of the resin formed in the wood from the fire-retardant chemical formulation (table 2).

All specimens exhibited some checks, cracks, or splits, but this may not necessarily have been due to the fire-retardant treatment as untreated controls also showed some checking. Most of the checking had occurred during the first 2 years' exposure. The least amount of checking was observed in the epoxy-coated shingles. Slight cupping of the shingles was noted with THPC and DPF treatments. Specimen panels with the pyrosoke treatment and sealer coating showed some discoloration or mottling possibly due to uneven erosion of the sealer coating. Untreated shingles were deep gray compared to medium to light gray for the treated shingles. Generally, the gray coloration was observed as more pronounced after 5 years' exposure than after 2 years'.

No visual evidence of biodegradation or incipient decay was observed. Some surface mold was noted on many of the specimens.

#### Fire Performance

Table 2 lists the results of the two fire performance tests on the treated and control shingles after no exposure and after 2 and 5 years' exposure.

**Untreated shingles.**—Usually all brands in the modified class C burning-brand test cause fire penetration of the untreated shingle covering and ignition of the roof deck

below. Fire penetration is primarily by glowing combustion because of the 12-mile-per-hour air flow over the specimen panel. A successful fire-retardant treatment must provide ignition resistance and glowing resistance.

In the severe mode of the modified Schlyter test the flames on the untreated shingles average 44 to 48 inches. Untreated western redcedar has a lower flame spread than most other species in the 25-foot furnace of ASTM E 84 (4). Redcedar lumber has a flame-spread index of 70 compared to 100 for the red oak standard in this test procedure.

The modified Schlyter test conducted in the severe mode with a T-head burner and 18,000 Btu per hour presents a severe fire exposure because of the chimney effect and reradiation between the two panels to promote the vertical spread of flame. In this test procedure, the ability of a treatment to cause self-extinguishment of the flaming on the specimen after removal of the igniting flame is an important indication of fire-retardant effectiveness.

**Fire-retardant epoxy paint.**—After 5 years' exposure the epoxy paint exhibited fair resistance in the burning-brand test with three failures out of 16 but had no resistance to spread of flame in the Schlyter test. Only one coat of paint was used on the panels, the same as in previous evaluations (7). The coating on approximately half of the specimen's surface area had eroded away. This erosion was not evident in the previous research on a different production lot of this paint. Ultraviolet degradation most likely contributed to this erosion. The laboratory weathering apparatus was not equivalent in ultraviolet radiation exposure to outdoor weathering. Two coats of this paint, or primer plus top coat, with better ultraviolet resistance should improve its performance.

Table 2.—Results of burning brand and severe-mode Schlyter tests on western redcedar shingle panels before and after outdoor exposure at Madison, Wis.

Shingle treatment	Chemical retention (dry) <sup>1</sup>	Burning brand tests				Weight loss after 5 years' exposure	Schlyter tests				Weight loss		
		Failures <sup>2</sup>		No exposure	2 years' exposure	5 years' exposure		Average flame spread		After 2 years' exposure	After 5 years' exposure		
		No	years'					Chemical retention (dry) <sup>3</sup>	No exposure	2 years' exposure	5 years' exposure		
Pct	Pct	Pct	Pct	Pct	Pct	Pct	in.	Pct	Pct	Pct	Pct	Pct	Pct
Untreated	—	15	14	16	3.7	—	48	47	44	1.7	3.2		
Fire-retardant epoxy paint <sup>4</sup>	—	0	0	3	2.8	—	27x	38	44	1.6	3.5		
THPC-1	6.2	0	0	0	4.0	4.1	42	41	39	2.3	2.9		
THPC-2	11.9	0	0	0	5.5	8.4	36	29x	36	3.2	4.5		
DPF-1	8.2	0	0	0	8.7	7.3	10x	18x	29x	4.8	6.9		
DPF-2	9.5	0	0	0	10.1	8.4	10x	22x	32x	6.5	9.8		
DP-1	6.3	0	0	0	8.7	6.2	10x	24x	35	5.9	9.8		
DP-2	7.7	0	0	0	10.2	7.2	10x	23x	36x	7.1	10.7		
Pyresote-1	7.1	0	15	16	12.8	—	—	—	—	—	—		
Pyresote-2	—	—	—	—	—	5.0	7x	41	43	5.8	10.5		
Pyresote-3 <sup>5</sup>	—	—	—	—	—	4.5	28	39	45	4.0	6.2		
Pyresote-4 <sup>6</sup>	4.7	0	0	4	6.4	—	—	—	—	—	—		
Pyresote-5 <sup>7</sup>	4.0	0	1	3	4.7	3.8	26	34	39	3.0	5.5		
UDFP-1	7.4	0	0	0	7.1	7.1	10x	20x	29x	3.7	6.9		
UDFP-2	10.3	0	0	0	7.0	7.7	11x	19x	32x	4.3	6.5		
NCX <sup>8</sup>	—	0	0	0	3.2	—	11x	12x	25x	2.0	3.6		

<sup>1</sup> Based on weight difference before and after treatment.

<sup>2</sup> Number of failures of 16 brands applied.

<sup>3</sup> Paint spread rates are 121, 114, and 128 ft<sup>2</sup>/gal for no exposure, 2 years and 5 years, respectively, for burning-brand specimens, and 127, 130, and 130 ft<sup>2</sup>/gal for no exposure, 2 years and 5 years, respectively, for the Schlyter specimens. All specimens received one coating of paint.

<sup>4</sup> "x" indicates flames on specimen were self-extinguishing after removal of the exposure gas flame at 3 minutes.

<sup>5</sup> Eight brands applied.

<sup>6</sup> Two applications of sealer coating at 15 to 17 g/ft<sup>2</sup> of shingle surface.

<sup>7</sup> Four applications of sealer coating at 21 to 24 g/ft<sup>2</sup>.

<sup>8</sup> NCX is a registered trademark of Koppers Company, Inc.; dry chemical retentions are not known.

**Tetrakis (hydroxymethyl) phosphonium chloride (THPC).**—THPC had no failures in the burning-brand tests after 2 and 5 years' exposure, but performance in the Schlyter test was poor before exposure at both light and heavy treatment levels, 4.1 and 8.4 pounds per cubic foot (pcf). There was little change in the Schlyter results after 2 and 5 years' exposure, indicating good leach resistance, but there was a continued low resistance to the vertical spread of flame in the Schlyter test. Approximately similar results were obtained in the prior evaluations, but with better Schlyter performance.

**Dicyandiamide-phosphoric acid-formaldehyde (DPF).**—This prereacted formulation with formaldehyde had no failures by burning brands. Schlyter results were quite good as flames on the specimens were observed to self-extinguish in all tests after removal of the igniting flame. Some leaching occurred as evidenced by Schlyter results of 10 inches before exposure and 29 and 32 inches after exposure and weight loss of 6.9 and 9.8 percent after 5 years' exposure for the two levels of treatment. The lower average flame spread results of the DPF-1 with chemical retention of 7.3 pcf compared to DPF-2 with 8.4 pcf (table 2) is ex-

plained on the basis that the Schlyter method is not precise enough to discriminate between high chemical treatment levels. This is true with most fire test methods.

**Dicyandiamide-phosphoric acid (DP).**—The performance of the DP system was the same as the DPF in the burning brand tests but somewhat poorer in the Schlyter because treatment levels were lower—6.2 and 7.2 pct. Weight loss by leaching was slightly more—9.8 and 10.7 percent after 5 years' exposure. The flaming in the Schlyter test failed to self-extinguish in one of the six tests conducted. The Schlyter results after 5 years were 35 and 36 inches with the flames nonself-extinguishing in the first test. The results indicate a rather critical leaching loss as evidenced by the loss of the self-extinguishing property. The previous research had also indicated some improvement with the dicyandiamide-phosphoric acid formulation prereacted with formaldehyde.

**Pyresote.**—The pyresote formulation, a nonleach-resistant, inorganic soluble-salt treatment of the interior type (table 1), was included in the study as a reference for the leach-resistant-type treatments. It was also used to determine if a water-repellent sealer coating could be used effectively with this type treatment to provide leach resistance. Specimen panels of pyresote-1 and pyresote-2 did not have any sealer coating. The results of the burning brand and Schlyter tests on these systems indicate heavy leaching loss of chemical retardants and that very little, if any, fire-retardant effectiveness remained after 2 years' exposure. The pyresote-5, with relatively low salt retention of 3.8-4.0 percent and with the heavier application of sealer coating, shows some remaining effectiveness after 2 years' exposure. There was relatively low weight loss of 3 percent in 2 years and 5.5 percent in 5 years' weathering, indicating the effectiveness of the sealer in reducing leaching. This system could be made more promising with heavier salt retention and improved sealer properties.

Other fire-retardant pressure treatments could be considered for use with a sealer, but periodic reapplication of the sealer would most likely be necessary. The resistance to biodegradation of the shingles by the chlorophenols in the sealer would be an additional advantage.

**Urea-dicyandiamide-formaldehyde-phosphoric acid (UDFP).**—Shingles and shakes treated with the UDFP system, developed at the Canadian Eastern Forest Products Laboratory,<sup>4</sup> are produced commercially in the United States with approval for class C roofing (9). The shingles used in this research study were treated at FPL and may not be at the same treatment level as those produced commercially. Also, the treated

shingles were not heat cured as is done commercially. These factors may have had an influence on the results.

There were no burning-brand failures after 5 years' exposure, but a 7 percent weight loss had occurred on the two specimen panels tested. The weight loss on the Schlyter panels was 6.9 and 6.5 percent. The Schlyter test results also showed some loss in effectiveness from 10 and 11 inches average flame spread before exposure to 29 and 32 inches after the 5 years' exposure, but in all tests the flames self-extinguished. Again, the Schlyter was not able to discriminate between high treatment levels.

**NCX.**—The two specimen panels exposed for 5 years with the commercial class C treated and labeled shingles had no burning-brand failures and the Schlyter flame spread was 25 inches and self-extinguishing. Weight loss from the panels during the 5 years was 3.2 and 3.6 percent. This is about the same as with the untreated panels, which would be expected to lose some water-soluble wood components or extractives. Good leach resistance was indicated, but some loss of fire-retardant chemical had occurred as shown by the Schlyter test results.

## Summary

**Fire-retardant epoxy paint.**—This particular paint system would not be acceptable as used in this study with a single coating application. The poor Schlyter results of 38 and 44 inches after 2 and 5 years' exposure with failure to self-extinguish indicate unsatisfactory performance.

**Tetrakis (hydroxymethyl) phosphonium chloride (THPC).**—Overall performance was not acceptable. Although the formulation used showed good resistance to leaching and to burning brands, it had low resistance, even at a high treatment level (8.4 pct), to flame spread as determined by the Schlyter test.

**Dicyandiamide-phosphoric acid-formaldehyde (DPF).**—Performance was acceptable, but high weight loss of 7 to 10 percent during 5 years' exposure may indicate questionable leach resistance and fire performance over a longer term.

**Dicyandiamide-phosphoric acid (DP).**—Performance was not quite as good as that of DPF. Prereaction of dicyandiamide and phosphoric acid with formaldehyde is indicated as preferable.

**Pyresote.**—Although pyresote is commercially acceptable for indoor use, this water-soluble salt treatment had essentially no fire-retardant effectiveness after 2 years of outdoor exposure to average U.S. rainfall. The necessity for wood shingle treatments to have good leach resistance to meet class C roofing requirements is definitely indicated.

<sup>4</sup> Eastern Forest Products Laboratory, Ottawa, Ontario, Canada.

**Pyresote with sealer coatings.**—Low weight losses indicate reduced loss of chemicals by leaching. However, the poor Schlyter flame-spread results and failure to self-extinguish preclude the acceptable use of this particular combination of pressure treatment and sealer. The use of a water-repellent and preservative sealer with less leach-resistant treatments that otherwise have acceptable fire performance—such as DP or DPF—may merit consideration.

**Urea-dicyandiamide-formaldehyde-phosphoric acid (UDFP).**—Resistance to burning brand and acceptable Schlyter performance show this system to be effective over the 5 years' exposure period.

**NCX.**—Best overall performance of all the treatments evaluated was exhibited by the commercially treated class C labeled shingles.

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## Appendix

This list of fire-retardant treatments is taken from the first report of preliminary data (7) from this research program. The code numbers match the code numbers of treatment systems used for the tests reported in this paper.

Table 1.—Description of fire-retardant treatments for western redcedar shingles and shakes

Code No.	Treatment method <sup>1</sup>	Description of treatment formulation
1	None	—
2	None (shakes)	—
3	Brush coating	One coat: Monoammonium phosphate 15%, water 85%.
4	Brush coating	Four undercoats: (AWPA Type D) Zinc chloride 5.25%, ammonium sulfate 5.25%, boric acid 3.75%, sodium dichromate 0.75%, water 85.0%. Three topcoats: Sealer A 80%, tricresyl phosphate 20%. Sealer A is a mineral spirits solution containing a water repellent, pentachlorophenol, and other chlorophenols; it meets Federal Specification TT-W-572 Type II.
5	Brush coating	One coat: Pentachlorophenol 3%, diesel oil 57%, fire-retardant chemical solution B 40.0%. Solution B is a water solution of sodium calcium borate and emulsifiers.
6	Brush coating	One coat: Pentachlorophenol 4.5%, diesel oil 85.5%, fire-retardant chemical solution C 10.0%. Solution C contains tris alkyl phenyl phosphate.
10	Brush coating	One coat: Forest Products Laboratory exterior house paint formulation with pure oxidizing alkyd, titanium dioxide, and cobalt and calcium naphthenate driers.
11	Brush coating	One coat: Same as Code No. 10 but with antimony oxide 8.4% of paint solids.
12	Brush coating	One coat: Same as Code No. 10 but with antimony oxide 16.7% of paint solids.
13	Brush coating	One coat: Fire-retardant epoxy paint D. Manufactured commercially in accordance with Military Specification MIL-C-46081.
14	Brush coating	One coat: Ashes (boiler) 14%, mica powder 12%, borax 6%; asbestos powder 4%, zinc oxide 4%, urea-formaldehyde glue 10%, water 50%. <sup>2</sup>
15	Brush coating	One coat: Fire-retardant asphalt emulsion E.
16	Brush coating	One coat: Tetrakis (hydroxymethyl) phosphonium chloride (80% in water) 44.1%, ethanolamine 2%, trimethylolmelamine 19.6%, urea 11.7%, water 22.6%.
17	Pressure impregnation	Treating solution: Sodium tetraborate decahydrate (borax) 18.9%, water 81.1%.
18	Pressure impregnation	Treating solution: Sodium tetraborate decahydrate 25.3%, monoammonium phosphate 6.6%, water 68.1%.

Table 1.—Description of fire-retardant treatments for western redcedar shingles and shakes—con.

Code No.	Treatment method <sup>1</sup>	Description of treatment formulation
19	Pressure impregnation	Treating solution: (AWPA Type B) Chromated zinc chloride 9.08%, boric acid 1.06%, ammonium sulfate 1.06%, water 88.80%.
20	Pressure impregnation	Treating solution: Monoammonium phosphate 2.59%, boric acid 2.59%, zinc chloride 4.31%, copper sulfate (anhydrous) 1.34%, sodium dichromate (anhydrous) 2.95%, water 86.22%. <sup>2</sup>
21	Pressure impregnation, double-salt treatment	Treating solution 1: Sodium tetraborate decahydrate 18.9%, water 81.1%. Treating solution 2: Zinc chloride 10%, water 90%.
22	Pressure impregnation, double-salt treatment	Treating solution 1: Sodium tetraborate decahydrate 37.8%, water 62.2%. Treating solution 2: Zinc chloride 15%, water 85%.
23	Pressure impregnation and brush coating	Treating solution: Sodium tetraborate decahydrate 25.3%, monoammonium phosphate 6.6%, water 68.1%. Brush coating: Three coats sealer A.
24	Pressure impregnation and spray coating	Treating solution: (AWPA Type D) Zinc chloride 5.95%, ammonium sulfate 5.95%, boric acid 4.26%, sodium dichromate 0.85%, water 83.0%. Spray coating: Five coats sealer A 80% tricresyl phosphate 20%.
25	Pressure impregnation	Treating solution: Tris (1-aziridinyl) phosphine oxide (72% in methylene chloride-acetone solvent) 20.8%, water 79.2%.
26	Pressure impregnation	Treating solution: Tris (1-aziridinyl) phosphine oxide (72% in methylene chloride-acetone solvent) 12.5%, water 87.5%.
27	Pressure impregnation	Treating solution: Tetrakis (hydroxymethyl) phosphonium chloride 34.31%, ethanolamine 1.96%, trimethylolmelamine 19.61%, urea 11.76%, water 32.36%.
28	Pressure impregnation	Treating solution: Tetrakis (hydroxymethyl) phosphonium chloride (80% in water) 5.02%, sodium hydroxide (50% in water) 0.87%, urea 0.80%, a liquid melamine 1.74%, water 91.57%.
29	Pressure impregnation	Treating solution: Tetrakis (hydroxymethyl) phosphonium chloride (80% in water) 10.04%, sodium hydroxide (50% in water) 1.74%, urea 1.60%, a liquid melamine 3.48%, water 83.14%.
30	Pressure impregnation	Treating solution: Dicyandiamide 9.3%, phosphoric acid (85%) 12.6%, water 78.1%.
31	Pressure impregnation	Treating solution: Dicyandiamide 6.82%, phosphoric acid (85%) 9.38%, formaldehyde (37%) 0.66%, water 83.14%. Solution prereacted.
32	Pressure impregnation	Treating solution: Dicyandiamide 9.10%, phosphoric acid (85%) 12.50%, formaldehyde (37%) 0.88%, water 77.52%. Solution prereacted.

Table 1.—Description of fire-retardant treatments for western redcedar shingles and shakes—con.

Code No.	Treatment method <sup>1</sup>	Description of treatment formulation
33	Pressure impregnation	Treating solution: Dicyandiamide 6.98%, phosphoric acid (85%) 9.45%, water 83.60%.
34	Pressure impregnation	Treating solution: Dicyandiamide 9.3%, phosphoric acid (85%) 12.6%, water 78.1%.
35	Pressure impregnation	Treating solution: Zinc sulfate 16.5%, zinc silicofluoride 18.1%, urea 10.4%, water 55.0%.
36	Factory tested	Commercial treatment, class C labeled by Underwriters' Laboratories, Inc.
37	Factory treated	Commercial treatment, class C labeled by Underwriters' Laboratories, Inc.

Applied on shingles unless shakes are specifically noted

<sup>1</sup> "A note on fire-resistive-cum-antiseptic composition and fire-resistive paint," by A. Purushotham, J. N. Pande, and J. S. Sud. Journal of the Timber Driers and Preservers Association, Vol. IX, No. 3, July 1963.

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Exterior weathering durability of some leach-resistant fire-retardant treatments for wood shingles: A five year report, by Carlton A. Holmes and Ronald O. Knispel, Madison, Wis., FPL, 1981.  
13 p. (USDA For. Serv. Res. Pap. FPL 403).

As part of a continuing study, shingles were treated by systems selected from previous research, and exposed for 2, 5, and 10 years. After 2 years' exposure all treatments showed acceptable results except for pyresote. After 5 years' exposure, all systems passed 80 percent or more of the burning board tests except for pyresote. All systems showed weakness in the Schlyter, but in four of the eight systems, flames were self-extinguishing.

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